REMARKS / ARGUMENTS

Claims 1 and 18 have been amended to further define the heating apparatus of the invention as a process heater for endothermic chemical reactions and to reflect that the distribution of the fuel nozzles along substantially the entire length of the oxidation chamber produces flameless, distributed combustion throughout the oxidation chamber, which is an important advantage of the apparatus of the present invention. Claims 13 and 19 have been canceled, which necessitated a change in the dependency of claims 16 and 21.

After almost six years in the USPTO and twice having gone to appeal only to have the prosecution reopened, the prosecution of this application appears to be essentially back to "square one" with a revised set of rejections (or revised theories for old rejections) based on the same references, Ruhl (EP 0 450 872) and Mikus (USP 5,255,742). A third reference, Minet et al, apparently is no longer being relied on for any of the rejections. Applicant is hopeful that in view of the above amendments and following remarks (which are believed to address the all of the issues raised in the subject Office action), that the prosecution of this application can at long last be brought to a successful conclusion, and a patent be allowed to issue on this important invention.

Before addressing the specific rejections, Applicant would like to briefly review the present invention and the claim limitations on which Applicant is relying to distinguish over the cited references. It is believed such a review might be helpful, since the current Office action contains two 102 rejections (one over Ruhl and the other over Mikus), while the rejections on appeal were based on 35 U.S.C. § 103. The new 102 rejection over Ruhl is particularly surprising since two previous 102 rejections based on Ruhl were overcome and withdrawn. This third 102 rejection based on same reference should likewise be withdrawn for reasons hereafter discussed.

The present invention relates to a flameless distributed combustion process heater apparatus which is highly effective in providing heat to high temperature reactions, particularly to endothermic chemical reactions, at a desired temperature profile and a controlled heat flux, at a sufficiently high rate to complete the process being conducted in the process chamber of the process heater apparatus. The flameless distributed combustion process heater apparatus of the present invention comprises three basic elements:

(1) An oxidation chamber containing a fuel conduit with a plurality of nozzles distributed along substantially the entire length of the oxidation chamber. The nozzles are spaced to produce combustion without a flame (i.e., "flameless" combustion) when fuel is mixed with preheated oxidant in the oxidation chamber.

(2) A preheater for heating oxidant to a temperature that when the oxidant and fuel are mixed in the oxidation chamber, the temperature of the resulting mixture will exceed the autoignition temperature of said mixture.

(3) A process chamber in a heat exchange relationship with the oxidation chamber whereby a controllable heat flux is provided to the process chamber at a sufficiently high rate to complete the process being conducted therein.

Various endothermic chemical reactions such as the steam reforming of hydrocarbons, dehydrogenation of ethyl benzene to produce styrene, and the like, can be conducted in the process chamber of the present apparatus.

The spacing of the fuel nozzles and the distribution of the fuel nozzles along substantially the entire length of the oxidation chamber results in flameless, distributed combustion in the oxidation chamber, which provides a controllable heat flux to the process chamber at a sufficiently high rate to complete the process being conducted therein. The heat flux may be controlled to provide a uniform temperature profile, but can also provide increasing or decreasing temperature profiles.

A basic advantage of the present invention is that the temperature profile, or flux of heat, may be controlled to whatever temperature profile is desired for a particular reaction. (Specification, page 6, lines 9-13) The benefits of the flameless distributed combustion process heater of the present invention include higher temperatures within metallurgical constraints, improved conversions, improved selectivities and/or product yields, reduced by-product production, reduced risk of tube failures due to "hot spots", lower energy consumption and low NO_x emissions. (Page 4 of specification, line 26, to page 5, line 9.)

The specific limitations being relied on to distinguish present apparatus over the cited references include the limitations that the oxidation chamber of the apparatus contain a fuel conduit with a plurality of fuel nozzles which are distributed "<u>along substantially the entire length of the oxidation chamber</u>", that <u>the fuel nozzles are spaced</u> so that the fuel is added to the oxidation chamber at a rate that <u>no flame results</u> when fuel is mixed the oxidant" in the oxidation chamber, and that the apparatus comprise

"process chamber" to which a controllable heat flux is provided at a sufficiently high rate to complete the process being conducted therein. These or similar limitations are included in independent claims 1 and 18, and the claims that depend therefrom.

Claims 1 and 18 have been amended to further define that the controllable heat flux provided by the oxidation chamber to the process chamber be sufficient to complete the endothermic chemical process conducted therein, and to reflect that distribution of the fuel nozzles along substantially the entire length of the oxidation chamber produces flameless, distributed combustion throughout the oxidation chamber.

In addition to the limitations recited in claims 1 and 18, Applicant is relying on the limitation in claims 17 and 24 that the oxidant be preheated by heat exchange with effluent from the process chamber to distinguish these claims from the cited art. Applicant considers the additional limitation recited in claims 17 and 24 to be a structural limitation, since it pertains to a particular configuration of the process heater of the invention in which the oxidant is preheated by heat exchange with gaseous effluent from an endothermic chemical process. Neither Ruhl nor Mikus teach or suggest this embodiment of Applicants process heater. Ruhl appears to contemplate use of an external preheater to preheat the oxidant, and states such preheaters are known in the art and are commercially available (Ruhl, page 5, lines 44-45). Mikus on the other hand contemplates preheating the oxidant, at least in part, by heat exchange between the combustion products rising in the well bore and combustion air and the fuel gas traveling down the flow conduits (Mikus, Col. 6, lines 12-15). There is no suggestion in Mikus of using effluent from a process chamber to preheat the oxidant, since the heater in Mikus does not have a process chamber and Mikus is not remotely concerned with endothermic chemical processes.

Claim Rejections – 35 U.S.C §102

The rejection of claims 1-7 and 13-24 under 35 U.S.C. § 102(b) as being anticipated by Ruhl is respectfully traversed.

Claims 13 and 19 have been canceled. Therefore the following remarks will be directed to the rejection of remaining claims 1-7, 14-18 and 20-24 as anticipated by Ruhl, which rejection is respectfully traversed.

As discussed above, a critical feature of the present apparatus is that the plurality of fuel nozzles in the fuel conduit be distributed along substantially the entire length of

the oxidation chamber. Since the oxidation chamber is in a heat exchange relationship with the process chamber, the distribution of the fuel nozzles along substantially the entire length of the oxidation chamber results in the provision of a controlled heat flux to the process chamber at a desired temperature profile and rate of flux. By controlling the temperature profile and rate of heat flux in the process chamber using the present apparatus one is able to achieve improved conversions, product yields, byproduct reduction, etc.

Contrary to the statement on page 5 of the current Office action, the plurality of fuel nozzles (64) in Fig. 4 of Ruhl, are not "distributed along substantially the entire length of said oxidation chamber (30,68)". All of perforations or holes 64 in Fig. 4 of Ruhl are spaced only in burner zone 68 which represents only a minor portion (appears to be roughly 20%) of the overall length of combustion tube (oxidation chamber) 30. There are no perforations in the upper portion or the lower portion of combustion tube 30. This uneven distribution of fuel nozzles in the oxidation chamber will result in an uneven temperature distribution in combustion tube 30, with the temperature in "burner zone" 68 of the combustion tube 30 being much greater than the temperature in the upper or lower portions of combustion tube. This conclusion is supported by the statement in Ruhl on page 5, lines 55-56, that plug 66, which is at the upper end of fuel tube 60, "need not resist very hot temperatures and thus could be made of graphite or heat resistant organic cement". Based on the location of the perforations in fuel tube 60 in Fig. 4 and the foregoing statement about plug 66, it is clear that Ruhl does not disclose "distributed' combustion, nor would the apparatus in Ruhl be able to achieve the same desired temperature profiles in a process chamber that are achievable by Applicant's apparatus. Therefore, Ruhl does not anticipate claims 1-7, 14-18 and 20-24, all of which require a plurality of fuel nozzles distributed "along substantially the entire length of the oxidation chamber". Claims 1 and 18 have been amended to explicitly recite that the instantly claimed apparatus produces "flameless, distributed combustion throughout the oxidation chamber".

It is noted that combustion tube 30 in the apparatus of Fig.4 of Ruhl runs the full length of the reactor. There are no walls or barriers dividing combustion tube 30 into separate sections or compartments. Oxidant and fuel are free to mix and combust anywhere in combustion tube 30. Hence, it would not be reasonable to define the oxidation chamber in Ruhl as being only that small portion of combustion tube 30 surrounding perforations 64. Clearly the entire combustion tube 30 is the oxidation

chamber in the reaction apparatus in Fig.4 of Ruhl. Since the fuel nozzles (perforations 64) in Ruhl are distributed over only a small portion (about 20%) of combustion tube 30 (i.e., in burner zone 68), Ruhl clearly does not meet the limitation that the fuel nozzles be distributed along substantially the entire length of the oxidation chamber. Accordingly, the rejection of claims 1-7, 14-18 and 20-24 as being anticipated by Ruhl should be withdrawn, which action is respectfully requested.

Claims 17 and 24 are not anticipated by Ruhl for the additional reason that Ruhl does not disclose preheating the oxidant by heat exchange with effluent from the process chamber. Instead, Ruhl appears to contemplate preheating the oxidant using a conventional commercial preheater. See page 5, lines 44-45, where it is stated: "Although no preheater is illustrated, such devices are known in the art and are commercially available". This statement certainly does not anticipate preheating oxidant using effluent from a process chamber.

Since Applicant is relying on structural limitations to distinguish the present apparatus over Ruhl (e.g., that the plurality of fuel nozzles be distributed along substantially the entire length of the oxidation chamber and that the process heater be configured to preheat the oxidant by heat exchange with process effluent), and not the manner in which the apparatus is intended to be used, nor the contents thereof, the rationale of *Ex Parte Masham*, 2 USPQ2d, 1647 (Bd. Pat. App. & Inter. 1987) and *Ex Parte Thibault*, 164 USPQ 666, 667 (Bd. App. 1969) does not apply.

The rejection of claims 1-4, 13 and 16-19, 21 and 24 under 35 U.S.C. § 102(b) as being anticipated by Mikus (USP 5, 255,742) is respectfully traversed.

Claims 13 and 19 have been canceled. Therefore, the following remarks will be directed to the rejection of claims 1-4, 16-18, 21and 24 as anticipated by Mikus, which rejection is respectfully traversed.

The heater disclosed in Mikus is designed to provide heat to subterranean formations to enhance oil recovery (Col.1 lines 9-10 and col. 3, lines 1-39). While the heater in Figs. 2-3 of Mikus has a fuel gas conduit, a combustion air conduit and a combustion gas conduit, it does not have a process chamber for conducting an endothermic chemical process, which is a limitation in each of the present claims.

Item (1) in Figs. 2-3 of Mikus does not represent a process chamber. Instead, it represents the "formation to be heated" (Mikus, col. 7, line 45). A "formation" is a

geological structure located hundreds or even thousands of feet underground, that basically consists of rocky materials which may contain oil and water trapped in the pores. Injection of heat into the formation causes thermal expansion of the water and oil trapped within the pores of the formation rock causing it to fracture. The hydrocarbons migrate through the small fractures created by the expansion and vaporization of oil and water. (See Mikus col.1, lines 24-36). The migrating hydrocarbons are recovered by pumping the oil to the surface using one or more recovery wells.

It is noted that the presence of pores containing entrapped oil and water in an underground formation <u>is an occurrence in nature</u>. The underground formation was not created by Mikus and cannot reasonably be said to be part of the structure of Mikus' heater. On the other hand, the "process chamber" in the present apparatus was developed by Applicant and is an integral part of the presently claimed flameless distributed combustion process heater apparatus.

Even if the pores in the underground formation in Mikus were somehow considered to be millions of tiny "process chambers", the "process" being conducted in these chambers would be that of heating of oil and water <u>to create fractures in the formation</u> to enhance the migration of oil to the recovery well. These <u>fractured</u> "process chambers" would not be suitable for conducting <u>endothermic chemical reactions</u>.

In this regard, the statement on page 7, line 19 of the current Office action that in the heat injector of Mikus "-the process chamber is used for an endothermic chemical reaction (abstract)" is not correct. While the heat injection method disclosed by Mikus is an "endothermic" process, it does not involve endothermic <u>chemical reactions</u>, such as steam methane reforming, or the production of styrene by the dehydrogenation of ethyl benzene. The heating of oil and water trapped in pores to create fractures in the formation is a <u>physical</u> rather than a <u>chemical</u> process. Moreover, the abstract in Mikus says nothing about the heat injector having a "process chamber". Perhaps the Examiner inadvertently confused the abstract for Ruhl (which does involve an endothermic reaction apparatus for conducting chemical reactions) with the abstract for Mikus (which makes no mention of process chambers or endothermic chemical reactions).

Thus, Mikus clearly does not meet the limitation in the present claims that the process heater comprise a <u>process chamber</u> suitable for conducting an <u>endothermic chemical process.</u>

In addition, Mikus does not meet the limitation that the oxidation chamber provide a controllable heat flux to the process chamber <u>at a sufficiently high rate to complete the</u>

endothermic chemical process being conducted therein. Because the rocky materials found in underground formations are good insulators, the heat flux required to heat the formation is relatively low, e.g., Mikus teaches that the heat is removed from the combustion chamber of the heat injectors at a rate of about 375 watts per foot of length. (Col.9, lines 67-68 to col. 10, line 1). While a heat flux of 375 watts per foot is sufficient to heat a subterranean formation, a heat flux of 375 watts per foot is an order of magnitude less than would be required to complete an endothermic chemical process such as the production of ethylene by the thermal cracking of hydrocarbons conducted in a process chamber. (See affidavit by Dr. Thomas Mikus, the inventor on the Mikus reference and a co-inventor on the present application.) Since, the relatively low rate of heat flux produced by the heat injector in Mikus would not be sufficient to complete the "endothermic chemical process" being conducted in the process chamber, this limitation in the present claims is not met by Mikus.

Thus, since the heater in Mikus does not have a process chamber suitable for conducting endothermic chemical reactions, and since the heat flux produced by the heater in Mikus is not sufficient to complete the endothermic chemical processes conducted in the process chamber, Mikus clearly does not anticipate the present claims, particularly as amended.

Claims 17 and 24 are not anticipated by Mikus for the additional reason that Mikus does not disclose preheating the oxidant by heat exchange with effluent from the process chamber. Instead, Mikus contemplates preheating the oxidant, at least in part, by heat exchange between the combustion products rising in the well bore and the combustion air and the fuel gas traveling down the flow conduits (Mikus, Col. 6, lines 12-15). There is no suggestion in Mikus of using gaseous effluent from an endothermic chemical process to preheat the oxidant, which is not surprising, since Mikus is not remotely concerned with endothermic chemical processes.

Applicant does not believe that the rationale of *Ex Parte Masham*, 2 USPQ2d, 1647 (Bd. Pat. App. & Inter. 1987) or the rationale of *Ex Parte Thibault*, 164 USPQ 666, 667 (Bd. App. 1969) is applicable to the present case, since Applicant is not relying on the manner in which the apparatus is intended to be used, nor the contents thereof, to distinguish over Mikus.

For all the above reasons, the rejection of claims 1-4, 16-18, 21 and 24 as being anticipated by Mikus should be withdrawn, which action is respectfully requested.

Claim Rejections – 35 U.S.C §103

The rejection of claims 5-7, 14-15, 20 and 22-23 under 35 U.S.C. § 103(a) as being unpatentable over Mikus (USP 5,255,742) is respectfully traversed.

Contrary to the statement made on page 10 of the current Office action, Mikus does not disclose all of the claim limitations of claims 5-7, 14-15, 20 and 22-23. As discussed above, the heat injector in Mikus does not have a process chamber which is an integral and essential element of the present process heater. The millions of pores in an underground formation are part of nature. They were not created by Mikus and cannot reasonably be said to be part of Mikus' heat injector.

Moreover, while Mikus does concern an "endothermic process" as stated in the Office action (i.e., the provision of heat at a relatively low rate of flux to an underground formation to enhance oil recovery), Mikus <u>does not</u> concern the provision of heat to an endothermic <u>chemical</u> process, which requires an order of magnitude higher rate of heat flux in order to complete a <u>chemical reaction</u> being conducted in a process chamber.

Since the heater in Mikus has no process chamber and has nothing at all to do with endothermic <u>chemical</u> processes, and since the rate of heat flux produced by the heater in Mikus is an order of magnitude less than required to complete typical endothermic chemical reactions, the statement on page 10 of the Office action that "An ordinary artesian at the time of the invention would have replaced the heaters in various endothermal process chambers with the process heater of Mikus for the purpose of providing more even temperature distribution and lowering the cost of said process chambers" is untenable. A skilled artesian in the chemical process art, considering the teachings of Mikus as a whole, would know that rate of heat flux produced by the heater in Mikus would be insufficient to complete typical chemical reactions, and therefore would not attempt to replace conventional heaters used for endothermic chemical reactions with the heater disclosed in Mikus. As stated in the Affidavit by Dr. Thomas Mikus, the inventor on the Mikus reference and a co-inventor on the present application, "Because of the significantly higher heat flux requirements of chemical process streams, the applicability of the flameless distributed combustion heat injectors to chemical process applications was unforeseen and not predictable".

The rejection of claims 1-7 and 13-24 under 35 U.S.C. § 103(a) as being unpatentable over Ruhl (EP) 0 450 872) in view of Mikus (USP 5,255,742) is respectfully traversed.

Claims 13 and 19 have been canceled. Therefore, the following remarks will be directed to the remaining claims 1-7, 14-18 and 20-24. As discussed above, Ruhl does not disclose the critical feature of the present apparatus recited in each of the present claims that the plurality of fuel nozzles in the fuel conduit be distributed <u>along substantially the entire length of the oxidation chamber</u>. The apparatus in Fig. 1 of Ruhl does not even have a plurality of fuel nozzles and clearly shows a flame in flame zone 50. The apparatus shown in Fig. 4 of Ruhl has a plurality of nozzles (64). However, they are not "distributed along substantially the entire length of said oxidation chamber" (combustion tube 30). Instead, all of perforations or holes 64 in Fig. 4 of Ruhl are spaced <u>in burner zone 68</u> which represents <u>only a minor portion (appears to be roughly 20%)</u> of the overall length of combustion tube (oxidation chamber) 30. There are no perforations in the upper portion or the lower portion of combustion tube 30. This uneven distribution of fuel nozzles in the oxidation chamber will result in an uneven temperature distribution in combustion tube 30, with the temperature in "burner zone" 68 of the combustion tube 30 being much greater than the temperature in the upper or lower portions of combustion tube 30, which allows the use of low temperature seals to seal the combustion tube to plates 16 and 18.

Apparently recognizing the apparatus in Fig. 4 of Ruhl by design produces a non-uniform temperature distribution, the Examiner on pages 12 and 15 of the subject Office action states "Further Ruhl discloses an embodiment wherein the process heater is designed and operated to provide uniform temperature profile (P6/L9-10)". The cited portion of Ruhl reads: "Even higher ratios are needed, it the reactor is to operate with low temperature differentials". The "even higher ratios" refers to the ratio of <u>the length of the combustion tube to its diameter</u> (See page 6, lines 7-9). The use of such higher tube length to diameter ratios permits the reactor to operate with lower temperature differentials. However, the use of such higher ratios would not create a uniform temperature profile in combustion tube 30, as long as nozzles 64 remained located in burner zone 68.

It is also stated on pages 12 and 15 of the current Office action that: "To enable operation at uniform temperature profiles the reference discloses embodiments where

the so called 'low temperature seals' are replaced by 'high temperature seals' (P6/L29-31) or where an alternative mode of operation is provided which allows said 'low temperature seals' to effectively operate at high temperatures (P6/L57-P7/L2). This statement is not believed to be accurate.

The first cited portion of Ruhl reads: "Another variation would arrange cocurrent flow of combustion gases and process gases. This scheme would require a hot seal on the exhaust end of the ceramic tubes." Ruhl goes on to state "The cold-end seal could be an O-ring or graphite foil type to allow tube thermal expansion." (Page 6, lines 31-32). From these statements, taken together, it is clear that in the disclosed variation, only the seals on the exhaust end of the combustion tubes are replaced with high temperature seals. The seals on the opposite "cold-end" of the combustion tubes in the vicinity of the feed inlet and air and fuel inlets would continue to have low temperature seals. Thus, instead of enabling "operation at uniform temperature profiles", this variation would also have an uneven temperature profile, i.e, higher temperature in the burner zone and the exhaust end of the combustion tube, and lower temperatures in "cold-end" of the combustion tube.

The second cited portion of Ruhl reads "The upper operating temperature of the graphite foil seals is limited by oxidation by the air present on one side. If a controlled very slow leakage of process gas is permitted to occur through the seal, this could sweep this air away from the seal material and permit the seals to exhibit long life at higher temperatures. Such an arrangement may be termed a purged seal condition."

A reasonable interpretation of this disclosure is a "purged seal condition" may be used to prolong the life of the graphite foil seals and permit their use at somewhat higher temperatures than if exposed to an oxidizing atmosphere. However, the use of a "purged seal condition" certainly would not allow low temperature graphite foil seals to be used in place of high temperature seals, such as fused glass or ceramic cement seals. Nor, would the use of a "purge seal condition" alter the fact that all of the fuel nozzles in the apparatus in Fig. 4 of Ruhl are located in the burner zone 68. The placement of the fuel nozzles in a minor portion of combustion tube 30 will inherently produce an uneven temperature distribution regardless of whether a "purged seal condition" is used or not.

Turning now to Mikus, Applicant strongly disagrees with the statement at the bottom of page 12 of the subject Office action, characterizing item (1) in Figs. 2-3 of Mikus as a "process chamber". Item (1) in Figs. 2-3 of Mikus represents the "formation to be heated" (Mikus, col. 7, line 45). A "formation" is a geological structure located

hundreds or even thousands of feet underground, that basically consists of rocky materials which may contain oil and water trapped in the pores. The "formation to be heated" is an occurrence in nature. It was not created by Mikus and cannot reasonably be said to be part of the structure of Mikus' heater. On the other hand the "process chamber" in the present apparatus is an integral part of the flameless distributed combustion process heater apparatus developed by Applicant and claimed in the present claims.

Even if the pores in the underground formation in Mikus were somehow considered to be millions of tiny "process chambers", the "process" being conducted in these chambers is heating of oil and water in the pores to create fractures to enhance oil recovery. These fractured "process chambers" would not be suitable for conducting endothermic chemical reactions. Moreover, the 375 watts per foot rate of heat flux taught by Mikus, while sufficient to heat underground formations which comprise rocky materials which are good insulators, would not be sufficient to complete an endothermic chemical process, which is now a limitation in claims 1 and 18, and the claims that depend thereon. Thus, Mikus clearly does not disclose a heater having a process chamber as an integral structural element, to which is provided a controllable heat flux sufficient to complete the endothermic chemical process being conducted therein.

Examiner's Basis for Combining Ruhl with Mikus

Despite the fact that the heaters in Figs. 1 and 4 in Ruhl, by design, have an uneven or non-uniform temperature distribution in order to allow the use of low temperature seals, on page 13 of the subject Office action the Examiner takes the position that:

> "It would be obvious to one of ordinary skill in the art at the time the invention was made to replace the heater in the apparatus of Ruhl with the heater of Mikus for the purpose of providing more even temperature distribution throughout the length of the burner and lowering the costs of said apparatus."

Applicant's Arguments as to Why Ruhl is Not Properly Combinable with Mikus

It basic patent law that the mere fact that references can be combined or modified does not render the resultant combination obvious unless the prior art also suggests the desirability of the combination. *In re Mills*, 916 F.2d 680, 16 USPQ 2d 1430

(Fed. Cir. 1990). Although a prior art device "may be capable of being modified to run the way the apparatus is claimed, there must be a suggestion or motivation in the reference to do so." 916 F.2d at 682, 16 USPQ2d at 1432.

Applicant submits that in the present case, there is no suggestion or motivation in the Ruhl or Mikus references for modifying them in the manner the Examiner has done. The Examiner's position that it would be obvious "to replace the heater in the apparatus of Ruhl with the heater of Mikus for the purpose of providing more even temperature distribution throughout the length of the burner and lowering the costs of said burner" is based on the erroneous assumption that an "even" or "uniform" temperature distribution throughout the length of the burner, which is taught by Mikus to be beneficial in heating subterranean formations, is also beneficial in heater used by Ruhl to provide heat to his endothermic reaction apparatus. This assumption is not correct, and in fact contrary to the disclosure in Ruhl.

As previously discussed, the heater (combustion tube 30) in the apparatus in Fig. 1 of Ruhl <u>does not have a "even" or "uniform" temperature distribution along the length of the combustion tube</u>, nor is there any teaching that an "even" or "uniform" temperature distribution is desired. To the contrary, Ruhl prefers the use of low temperature seals 32 to hold the combustion tube in place. Therefore, the combustion tube in Fig. 1 of Ruhl intentionally has the highest temperatures in flame zone 50 (in the middle of combustion tube 30), with lower temperatures at the upper and lower portions of the combustion tube to allow the use of low temperature seals to join the combustion tube to the tube sheets.

Likewise the heater in Fig. 4 of Ruhl does not have an "even' or "uniform" temperature distribution since all of the fuel nozzles in Fig. 4 are in the "burner zone" 68 in the middle portion of combustion tube 30. There are no fuel nozzles in the upper portion or lower portion of the combustion tube 30. Consequently, these portions will have lower temperatures than the temperature in the "burner zone" 68, thereby allowing the use of low temperature seals. Lower temperatures in the upper portion of combustion tube also allows the use of a plug 66 at the upper end of the fuel tube "which need not resist very hot temperatures".

Since the heaters in both Fig. 1 and Fig. 4 of Ruhl by design have a <u>non-uniform</u> temperature distribution along their length, and since there's no indication in Ruhl that an "even" or "uniform" temperature distribution is desirable, <u>it would not be obvious</u> to one skilled in the art to replace the heater in the apparatus of Ruhl with the heater in Mikus

for "the purpose of providing more even temperature distribution throughout the length of the burner", as contended by the Examiner. The teaching or suggestion to combine these references and a reasonable expectation for success must both be found in the prior art, and not based on applicant's disclosure. *In re Vaeck*, 947 F.2d 488, 20USPQ2d 1438 (Fed. Cir. 1991). Applicant submits that in the present case the prior art does not suggest replacing the heater in either Fig. 1 or Fig. 4 of Ruhl with the heat injector in Mikus, nor does the prior art create a reasonable expectation that such substitution would be successful.

The fact that the heaters used in Figs. 1 and 4 of Ruhl have a non-uniform temperature distribution along their length, while the heater in Mikus is designed to produce an "even" or "uniform" temperature distribution, again illustrates the differences between the problems to which Ruhl and Mikus were directed, and why these references are not properly combinable. Ruhl wanted to design a reactor apparatus with a heater which could provide a high heat flux sufficient to complete the particular endothermic chemical reactions he was interested in, yet low temperature seals could be used in the reactor to connect the combustion tubes to the tube sheets. Therefore, Ruhl designed combustion tube 30 to have lower temperatures in the general vicinity of the seals with higher temperatures in the middle of the heater (i.e., in "flame zone" 50 in the case of Fig.1, and in "burner zone" 68 in the case of Fig. 4).

Mikus, on the other hand, was concerned with recovery of hydrocarbons entrapped in pores in an underground formation and found that the provision of uniform heat to the formation at a relatively low heat flux was beneficial. Mikus was not concerned with designing compact reaction apparatuses, or conducting endothermic chemical reactions which require a high heat flux, or joining combustion tubes to tube sheets with low temperature seals. Since the problems to which Ruhl and Mikus are directed, and the solutions they found, are quite different, it clearly would not be obvious to replace the heater in Ruhl with the heater of Mikus " for the purpose of providing more even temperature distribution throughout the length of the burner". Such substitution would not solve the problems to which Ruhl was directed, nor achieve the benefits Ruhl desired.

Applicant further submits that it would not be obvious to replace the heater in the apparatus of Ruhl with the heater of Mikus for the purpose of "lowering the costs of said apparatus". The heater in Fig. 1 utilizes combustion with flames, which will generate a high temperature in the flame zone, and lower temperatures in the upper and lower

portions of the combustion tube which permits the use of low temperature seals to join the combustion tubes to the tube sheets. It is doubtful that substituting the relatively low heat flux flameless heater of Mikus for the flame-type heater used in the apparatus of Fig.1 of Ruhl would provide sufficient heat flux to complete the desired endothermic chemical reactions. If it did, it is likely that the temperatures in the upper and lower portions of the combustion tubes would be too high to use the low temperature seals favored by Ruhl. Thus, the substitution of heaters suggested by the Examiner would involve a significant redesign of the reactor apparatus in Fig. 1 of Ruhl, and may necessitate the use of high temperature seals, which could actually increase the cost of the apparatus.

Applicant submits that when the Ruhl and Mikus references are considered as a whole, rather that suggesting to one skilled in the art to replace the heater of Ruhl with the heat injector of Mikus, they provide at least two significant reasons for <u>not replacing</u> the heater of Ruhl with the heat injector of Mikus. (1) The heaters used to provide heat to the endothermic reaction apparatuses in Figs. 1 and 4 of Ruhl have a <u>non-uniform temperature distribution by design</u>, and there is no indication that an even temperature distribution is desired, and (2) endothermic chemical reactions, such as the reforming of light hydrocarbons, which are of interest to Ruhl, require far greater heat flux than the approximately 375 watts per foot produced by the heater injectors used by Mikus to heat subterranean formations, as stated in the affidavit by Dr. Thomas Mikus.

It is noted that Ruhl does teach on page 5, lines 38-39 that "as many as many thousands of combustion tubes could be incorporated in an appropriate size reformer apparatus". However, this disclosure refers to the small diameter, ceramic combustion tubes preferred by Ruhl, which have higher temperatures in the flame zone or burner zone in the middle portion of the combustion tube and lower temperatures at the ends to allow the use of relatively low temperature seals. Thus, the fact Ruhl teaches many combustion tubes having small diameter and an <u>uneven</u> temperature distribution can be used in a reformer apparatus, does not provide a motivation to replace these combustion tubes with the quite different type and size combustion tube disclosed in Mikus, which not only have larger diameter, but which also produce an <u>even</u> temperature distribution, which is contrary to the combustion tube design in Ruhl.

For the foregoing reasons, claims 1-7, 14-18 and 20-24 are believed to be patentable over Ruhl in view of Mikus. Accordingly, it is respectfully requested that the rejection of these claims under 35 U.S.C. § 103(a) be withdrawn.

As discussed above, Applicant is relying on structural limitations and not on the manner in which the claimed apparatus is intended to be used, nor the contents thereof, to differentiate the claimed apparatus from the prior art. Thus, the rationale of *Ex Parte Masham* and *Ex Parte Thibault* does not apply.

In addition to the structural limitations recited in claims 1 and 18, Applicant is relying on the limitation in claims 17 and 24 that the oxidant be preheated by heat exchange with effluent from the process chamber to distinguish these claims from the cited art. Applicant considers the additional limitation recited in claims 17 and 24 to be a structural limitation, since it pertains to a particular configuration of the process heater of the invention in which the oxidant is preheated by heat exchange with gaseous effluent from an endothermic chemical process. Neither Ruhl nor Mikus teach or suggest such this embodiment of Applicants process heater. Ruhl appears to contemplate use of an external preheater to preheat the oxidant, and states such preheaters are known in the art and are commercially available (Ruhl, page 5, lines 44-45). Mikus on the other hand contemplates, preheating the oxidant, at least in part, by heat exchange between the combustion products rising in the well bore and combustion air and the fuel gas traveling down the flow conduits (Mikus, Col. 6, lines 12-15). There is no suggestion in Mikus of using gaseous effluent from an endothermic chemical process to preheat the oxidant. Mikus, of course, is not remotely concerned with endothermic chemical processes, as discussed above.

For all the foregoing reasons and in view of the amendments and Dr. Mikus' affidavit, it is believed that the remaining claims in the application (claims 1-7, 14-18 and 20-24) are patentable. Accordingly, it is respectfully requested that these claims be allowed, and the application at long last be passed to issue.

Respectfully submitted,

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